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Why the CDM can reduce carbon leakage

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Sammendrag:. Karbonlekkasje er en viktig bekymring fordi det kan redusere miljøeffekten til Kyotoprotokollen. Protokollen åpner for bruk av fleksible mekanismer som kan redusere kostnadene knyttet til å oppfylle målene som protokollen fastsetter – en av disse er den grønne utviklingsmekanismen (CDM). CDM kan potensielt redusere karbonlekkasjen betydelig fordi CDM reduserer den relative konkurransemessige ulempen for Annex B land ved å begrense utslippene av klimagasser. Den økonomiske intuisjonen bak dette forholdet blir først utforsket i en teoretisk analyse, og deretter numerisk ved hjelp av en generell likevektsmodell. Resultatene antyder - dersom man gjør regnskap for lekkasje på en passende måte, og med realistiske antakelser om bruken av CDM, at CDM har potensial til å redusere omfanget av karbonlekkasje med rundt tre femtedeler.

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Abstract: Carbon leakage is an important concern because it can reduce the environmental effectiveness of the Kyoto Protocol. The Clean Development Mechanism, one of the flexibility mechanisms allowed under the protocol, has the potential to reduce carbon leakage significantly because it reduces the relative competitive disadvantage to Annex B countries of restricting greenhouse gas emissions. The economic intuition behind this mechanism is explored in a theoretical analysis. It is then analyzed numerically using a CGE model. The results indicate that, assuming appropriate accounting for leakage and under realistic assumptions on CDM activity, the CDM has the potential to reduce the magnitude of carbon leakage by around three fifths.

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1 Introduction

Economic theory predicts that a climate regime that imposes costs on its participants, but has less than full participation, will result in carbon leakage that will reduce the environmental effectiveness of the regime. Any auxiliary mechanisms that bridge the cost gap between the participating and non-participating countries (or sectors/actions) can reduce or eliminate this problem.

The Kyoto Protocol establishes binding greenhouse gas (GHG) emission caps for a first commitment period (2008-2012). These emission caps apply to participating Annex B countries.[1] This costly restriction is expected to result in carbon leakage (also called emissions leakage); an increase in carbon emissions in non-Annex B countries due to the costly restrictions imposed in participating (Annex B) countries. This expected increase in emissions in non-Annex B countries would, if it should prove as significant as some studies suggest, be a serious challenge to the environmental integrity of the Kyoto Protocol.

There is a substantial body of literature that explores carbon leakage (see Hourcade and Shukla 2001 for an overview). This literature also addresses the issue of how one auxiliary mechanism – international emissions trading (IET) – can reduce carbon leakage (e.g. Bernstein et al. 1999). How the Clean Development Mechanism (CDM) – another auxiliary mechanism may also influence carbon leakage *through market prices* has, however, so far been largely overlooked.

The purpose of this paper is to try to fill this gap in the existing literature by attempting to answer the research question: To what extent can the CDM influence carbon leakage through the emissions trading market under the Kyoto Protocol?

It is not the purpose of this paper to provide realistic estimates of carbon leakage as such, but to see how the CDM might influence this leakage. Still, it is not at all without interest how great carbon leakage might turn out to be. If carbon leakage should turn out to be small, the problem is not critical with respect to environmental effectiveness (or competitiveness effects), and the issue of to what extent the CDM can reduce carbon leakage becomes less relevant. If, however, carbon leakage should turn out to be sizeable, the questions of whether and by how much the CDM can reduce carbon leakage will be highly relevant; especially to the extent that carbon leakage and relocation of industries to non-Annex B countries is used as an argument against Kyoto-type climate agreements.

The first section of the paper contains a brief review of the relevant literature on carbon leakage and the CDM. The issue is first analyzed theoretically in section 2, and then numerically using a computable general equilibrium (CGE) model. The model is described in section 3, and the results are reported in section 4. Section 5 concludes the paper.

1.1 The literature on carbon leakage and the CDM

Carbon leakage has been an important issue in the literature concerning the Kyoto Protocol as it implies that the environmental benefits of mitigation in some countries are offset by higher emissions in countries without binding caps (see for example Hourcade and Shukla 2001,

[1] The Annex B countries are the 39 industrialized countries with a quantified emission limitation listed in Annex B of the Kyoto Protocol. Of these, only countries that have ratified the Kyoto Protocol will be bound by these emissions caps. Currently the United States and Australia have opted out of ratification. Annex 1 countries are the 36 countries listed in Annex 1 of the UNFCCC. Too avoid confusion we will always refer to Annex B and non-Annex B countries. Keep in mind that the countries that have not ratified the Kyoto Protocol do not belong to either group.

Sijm et al 2004, Manne and Richels 1999). Sijm et al (2004, p. 12) defines carbon leakage as "the ratio of policy-induced increase of emission from a non-abating country over the reduction of emission by an abating country." For the purposes of this paper it is necessary to adopt a more specific version of this definition: "Policy-induced" will be taken to mean *any changes in emissions brought about as a result of the implementation of the Kyoto Protocol*, and "increase of emissions" will be understood as *net increase in global emissions* (excepting the committed emissions reductions of the Annex B countries).[2]

There are several factors that influence the magnitude (and sign) of carbon leakage; economic structure, trade patterns, tariffs, capital mobility, new technologies and technology diffusion, to mention some of the most important. Several studies have estimated the magnitude of carbon leakage using applied equilibrium models that capture the effects of several of these factors. Most of these studies estimate the global rate of carbon leakage to be between 5 and 20 percent of the emissions reductions projected to be required by Annex B countries to meet their Kyoto commitments (for an overview see Hourcade and Shukla 2001, or Sijm et al. 2004). However, Babiker (2005) claims that the magnitude of the leakage might be significantly greater; he estimates the global carbon leakage rate to range between 50 and 130 percent. Because of carbon leakage the Kyoto Protocol could thus even lead to an overall *increase* in global emissions. In contrast, two recent studies find that if endogenous technological change is taken into account, estimates of carbon leakage may be significantly reduced. Golombek and Hoel (2004) use a two-country model to show that with endogenous technological change, it is not longer obvious that carbon leakage will be positive – and that it may even be negative in some cases as technology diffusion can reduce emissions. Di Maria and van der Werf (2005) also use a two country-model with endogenous technological change and reach very similar conclusions. They show that if we allow for induced technological change, carbon leakage will be lower than otherwise, and may even be negative. What drives this result is that directed technical change reduces the incentive to pollute for the non-participating country (as the productivity of energy is reduced), and it may even be induced to reduce its emissions when the relative demand for energy is sufficiently elastic.

The CDM is one of the project based mechanisms allowed under the Kyoto Protocol. The mechanism allows Annex B countries or firms in Annex B countries to generate Certified Emission Reduction units (CERs) by investing in projects that reduce emissions in non-Annex B countries (UNFCCC 2005a). CERs generated under the CDM can be used by Annex B countries towards meeting their quantified emission reduction commitments under the Kyoto Protocol.

The CERs generated by the project are calculated as the difference between a *baseline* and the actual (projected) emissions – adjusted for any leakage that may occur. UNFCCC (2005a: §44) defines the *baseline* for a CDM project activity as "the scenario that reasonably represents the emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity".

To the extent that the CDM literature has addressed leakage, it has for the most part focused on other types of leakage than those that occur through markets. Vöhringer et al. (2006) identify three types of leakages that have been discussed in the literature; economic leakage, ecological leakage and knowledge leakage. These are not necessarily leakages in themselves, but become so if they are not properly accounted for (see Geres and Michaelowa 2002 for a proposed qualitative method to deal with leakage effects).

[2] One important reason for choosing *net increase in global emissions* rather than just *increase in non-Annex B emissions* is that the CDM allows a relocation of emissions between Annex B and non-Annex B countries; i.e. a decrease in non-Annex B countries that has a zero net effect globally.

This paper will focus on economic leakages. Vöhringer and his colleagues distinguish between two types of economic leakage – direct economic leakage and market leakage. *Direct economic leakage* is the increase in emissions resulting from changes in the activity's demand for input factors and intermediates (for example the emissions associated with producing and constructing a windmill). This type of leakage is sometimes accounted for in baseline estimates, and there are no substantial problems or controversies regarding what constitutes direct leakage (e.g. the emissions resulting from the energy required to build a small-scale hydropower dam).

Market leakages are leakage effects that are transmitted through price changes. Vöhringer et al. (2006) argue that these leakages are neglected by most CDM project developers because the effect of *one* CDM project on market prices seems to be insignificant; but aggregate effects may be significant. The purpose of their paper is to propose a framework for attributing market leakage to individual CDM projects. What is interesting in this context though, is the fact that while they acknowledge the importance of using general equilibrium models to quantify market leakage, they ignore the IET market when they discuss the most relevant markets (fossil fuels, electricity, timber and land are mentioned). In this paper the price signals transmitted through the international emission trading market will be a key focus.

Bollen et al. (1999) is one of the few papers to explicitly address this linkage between the CDM and carbon leakage. When it comes to the overall effect of the CDM on carbon leakage, they find that the CDM will *increase* global leakage. The reason is the existence of local energy markets: While emissions reductions under the CDM may be substantial, the input factors allocated to energy supply sectors will not easily move away from these sectors. This produces a downward pressure on local energy prices, and energy-intensive sectors increase their energy demand. Consequently emissions from these sectors increase.

2 How and why the CDM can reduce global carbon leakage

Carbon leakage occurs when there is a price differential (in actual prices or shadow prices) on GHG emissions between countries (and a commitment to reduce emissions). In the case of the Kyoto Protocol, the price differential is brought about by policies to reduce emissions in Annex B countries that will create a significant and positive price on emissions, while the price on emissions in non-Annex B countries will be low (or zero, if no climate policies whatsoever are implemented). In general, the restrictions on emissions will increase the cost of activities that emit greenhouse gases. This may provide sufficient incentives for industries (especially emissions intensive industries) to relocate from Annex B countries to non-Annex B countries, or the increased cost may reduce their competitiveness to the extent that their competitors in non-Annex B countries will increase their output (and emissions). The increased cost of emitting greenhouse gases will reduce demand for fossil fuels, and this will in turn reduce international prices for fossil fuels. Demand for fossil fuels might thus be expected to increase in non-abating countries (non-Annex B countries). The increased demand for fossil fuels will then result in increased emissions (either as output expands or as energy use becomes less efficient). As a result of this relocation of emitting activities, emissions in non-Annex B countries will be higher than they would have been without implementation of the Kyoto Protocol.

This is, of course, a simplified explanation of the mechanisms underlying carbon leakage. Terms-of-trade effects, economic structure, substitution possibilities and tariffs all influence where and by how much emissions increase (or even decrease) in non-abating countries.

Some of these factors will be analyzed to provide more detailed explanations in the results section. These additional factors will not change the basic market mechanism of carbon leakage though:[3] Carbon leakage will reduce the environmental effectiveness of the Protocol (and some studies even suggest it could make the environmental effect negative).

The magnitude of carbon leakage will depend on the size of the price differential; a higher differential should increase carbon leakage. In principle, an activity that reduces the price differential on emissions between Annex B and non-Annex B regions should then decrease the magnitude of carbon leakage. The Kyoto Protocol allows the use of three flexibility mechanisms to reduce the cost of meeting the emissions caps: International Emission Trading (IET), Joint Implementation (JI) and the Clean Development Mechanism (CDM) (UNFCCC 1997). To the extent that use of these flexibility mechanisms reduces the cost of emissions in Annex B countries, they should also reduce carbon leakage to some extent, as this would reduce the price differential.[4] The CDM is, however, different from IET and JI in some important respects: The CDM will not equalize the cost of emissions across countries to the extent that IET and JI can do it – because participation in the CDM is not expected to be 100%, and also (but linked to this) because transaction costs are expected to be greater. Furthermore, because CDM projects entail costs in the CDM host countries, this can produce carbon leakage within and between CDM host countries. For these reasons, it is less straightforward to predict how the CDM will influence carbon leakage than how IET or JI will influence it (and, as the literature review indicates, even this is far from being a straightforward issue).

When analyzing the influence of the CDM on global rates of carbon leakage it is useful to see it as consisting of two different elements. The first is that CDM projects generate credits (CERs) that can be used by Annex B countries toward meeting their obligations under the Kyoto Protocol. These credits will reduce the permit prices in the IET market, and the reduced price on emissions can in turn be expected to reduce carbon leakage. The second element is that the implementation of CDM projects will result in a reallocation of resources in the host countries. This reallocation will change emissions within the CDM host countries. It *may* increase emissions through such a mechanism as Bollen et al. (1999) identified; CDM projects reduce energy prices in local markets and this results in increase energy use and increased emissions. While it is likely that the implementation of CDM projects will reduce the demand for fossil fuels (and hence also reduce the price), there are other effects that might be more important: To the extent that CDM projects involve substituting from energy goods to non-energy goods, the price of non-energy goods is likely to increase at the same time as the price of fossil fuels is reduced. As the markets for non-energy goods tend to be less internationally competitive that the markets for fossil fuels, the price sensitivity is likely to be higher for non-energy goods. Furthermore, many CDM projects will involve the non-CO_2 gases, and these projects are likely to produce an increased demand for non-energy goods without any significant changes in the demand for energy goods. The overall result *may* therefore also be that costs increase to the extent that emissions-intensive activities (which do not participate in CDM projects) decrease their emissions.

The overall influence of the CDM on carbon leakage depends on the relative strength of the two mechanisms (and the sign of the second), and how the two interact to produce a net result that may not be the sum of their individual contributions to leakage.

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[3] Please note that this paper deals with the *market* leakage effects of the CDM. Knowledge spillovers or technology diffusion is not considered here.

[4] While IET will decrease leakage to non-Annex B countries as long as it reduces the cost of abatement, it is not obvious that IET will decrease global emissions. The reason is that IET allows Russia and a few other countries to sell excess permits (hot air). Without IET these excess permits could not have been "used".

Assuming that the CDM can reduce carbon leakage in theory, it is not, however, obvious that the full potential for reducing leakage can be realized in practice. The definition of the baseline (see introduction) implies that CDM projects should account for how their BAU emissions change as a result of other CDM projects being implemented - as the baseline is the emissions that "would occur in the absence of the proposed project activity". In other words, if BAU emissions are reduced for example due to price changes brought about by the implementation of other CDM projects, this should be accounted for. Furthermore, paragraph 47 (UNFCCC 2005a) states that "[t]he baseline shall be defined in a way that CERs cannot be earned for decreases in activity levels outside the project activity or due to force majeure." Thus, a project cannot claim credits for having reduced the baseline of another CDM project. This means that if a CDM project does reduce leakage, no one can claim credits for these emission reductions, and the potential should be realized. It is, however, far from trivial to account for the leakage effects of other projects in practice. While it will be assumed in this paper that leakage can be appropriately accounted for, Kallbekken et al. (2006) discuss which baseline methodologies might be used in practice, and what this implies for the relationship between the CDM and carbon leakage.

3 The model

The DEEP CGE model is used to analyze the relationship between the CDM on carbon leakage. The DEEP model is a multi-sector and multi-region intertemporal computable general equilibrium model. The structure of production and demand has been adopted from the GTAP-EG model by Rutherford and Paltsev (2000) – with some modifications. The economic data used in the DEEP model is the GTAP (v6) data base (Dimaranan and McDougall 2006) - which provides input-output data for each region, bilateral trade data, and information on taxes and tariffs. The emissions data is from the GTAP/EPA Project "Towards an Integrated Data Base for Assessing the Potential for Greenhouse Gas Mitigation". A full description of the DEEP model, including assumptions on elasticities and the dynamics of the model, can be found in Kallbekken (2004).

For the purposes of this paper the time horizon will be 2001-2012. The sectors and regions are listed in table 3.1. Economic and emissions growth is assumed to follow the International Energy Outlook 2005 projections (EIA 2005). Both economic and emissions growth is moderate in mature market economies in this projection (though significantly higher for North America than for Europe and Asia), and high in emerging economies.

Regarding implementation of the Kyoto Protocol, it is assumed that the current EU emissions trading scheme will be extended to include the aluminium and chemical sector from 2008, but that it will otherwise be implemented as it is today. Russia is assumed to implement a somewhat more comprehensive emissions trading scheme than the EU in that it will also include other manufacturing and services.[5] For the other Annex B countries an emissions trading system similar to the EU ETS is assumed, but with gas (production and distribution) also included. For all Annex B countries only CO_2 emissions will be covered by the emissions trading system. Furthermore it is assumed that no hot air is sold on the market (this assumption will be relaxed in the sensitivity analysis). For the emissions that are not covered by the emissions trading scheme it is assumed that other, but less stringent measures will be implemented. In the model this is done by establishing a national "shadow" emissions trading systems with an emissions reduction requirement only half as stringent as the IET (ratio of required cuts to BAU emissions is half as large as for sectors in the IET). Note that

[5] Whether Russia will actually implement an emissions trading system or whether Russia will instead focus on promoting JI projects *in the same sectors* has no numerical impact on our estimates (given our other assumptions).

the USA and Australia have not ratified the Kyoto Protocol, and therefore do not participate in IET.

Region	Sector
• European Union	• Coal
• Russia	• Refined petroleum
• Rest of Annex B	• Crude oil
• China	• Gas
• India	• Agriculture
• Brazil	• Energy intensive sectors
• Africa and Latin America	• Other manufacturing and services
• Asia	• Electricity
• Non-participating regions*	• Capital good

* Predominantly USA and Australia

Table 3.1: Regions and sectors in the model

Three main scenarios were created for this project. The first, which is called *No-Kyoto*, is used to find what emissions would have been without implementation of the Kyoto Protocol (the basis of comparison for finding carbon leakage). The *IET-only* scenario is used to find the magnitude of carbon leakage with implementation of the Kyoto Protocol (with international emissions trading), but without any CDM projects. Finally, the *CDM* scenario assumes implementation of the Kyoto Protocol with CDM projects implemented. For the latter scenario some important modelling choices have to be made:

The CDM is modelled in a way that is conceptually equivalent to an emissions trading scheme: If one regards the BAU emissions of the CDM host countries as their baseline, then any reduction in emissions below this level can be regarded as generating CDM credits (see Kallbekken and Westskog 2005). In addition to CO_2 emissions, both CH_4 and N_2O emissions will be covered by this scheme.

The CDM does, however, differ from an emission trading system in three important respects:

(1) Not all profitable CDM projects will be implemented as there are several significant barriers to implementation, such as lack of capacity to identify and assess potential projects in host countries, and lack of awareness of the CDM and its benefits amongst potential financers. Ellis et al (2004) argue that these barriers also include financial and institutional barriers, risk and uncertainties associated with generating CERs, delays in approving CDM project activities and methodologies, and other barriers such as difficulties in matching potential projects with potential investors, or barriers for investment by non-domestic entities. The term *participation rate* will be used to describe the share of the potentially profitable projects that is actually implemented. Because it is difficult to provide a good estimate of the participation rate, the analysis will be carried out across a range of 0 to 95% participation.[6] As

[6] This is similar to how Jotzo and Michaelowa (2002) scale back their abatement cost curves. However, as abatement costs are implicit in our model, we do not as such scale back abatement cost curves, but vary the share of total emissions that can participate in the CDM.

results turn out to be highly dependent on this variable, it will be an important part of the analysis. It is important to note that the participation rate refers to the share of the industrial emissions for which all profitable projects are carried out. It does not refer to the share of firms actually carrying out CDM projects (there are no firms, only sectors in the model).

(2) Many studies argue that CDM is likely to entail larger transactions costs than emission trading. (See for instance de Gouvello and Coto 2003, Jotzo and Michaelowa 2002, Michaelowa and Jotzo 2005 and Michaelowa et al 2003). In the CDM scenario transaction costs of 20% will be imposed – following Michaelowa and Jotzo (2005) where transaction costs account for 20% of the permit price for the marginal projects.[7]

(3) The baseline for the CDM projects (i.e. the number of permits allocated) have to be updated with respect to how other projects affect the baseline for each project. This problem is done by using a stepwise procedure to set the baseline: The participation rate is increased by 1 percentage point in each step to find out how this changes the business-as-usual emissions of the activities not taking part in the CDM, and when another percentage share of the emissions are included in the next step, the baseline for these emissions reflect this influence (the change in leakage).

4 Results

Under the *No-Kyoto* scenario the emissions covered in the model are projected to grow to 11.9 Gt Ce per year during the first commitment period.[8] The Annex B countries are committed to reducing their emissions by a total of 445 Mt Ce per year, which corresponds to a 3.7% cut in global emissions as compared to the N*o-Kyoto* scenario.

In the *IET-only* scenario the permit price is $27.2/t Ce. This increase in the cost of emissions in Annex B countries results in an increase in emissions in CDM host countries and non-participating countries of 28 Mt Ce per year. This corresponds to carbon leakage of 6.3%. Compared to other estimates in the literature (typically 5-20%, Hourcade and Shukla, 2001) this is a relatively low estimate.[9]

In the *CDM* scenario the generation of CERs from the CDM results in a significant decrease in the international permit price (see figure 4.1). While the permit price is $27.2 at 0% participation, it is roughly halved ($14.4) if the participation rate is 10%, and the permit price drops below $2.0 for (perhaps unrealistically high) participation rates above 75%. The volume of CDM sales climbs from 0 to 100 Mt Ce/year as the participation rate increases from 0 to 10%, and levels off at around 240 Mt Ce/year as the participation rate approaches 100% (see figure 4.1).

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[7] 20% transaction costs is a relatively high estimate. A high estimate was chosen because other assumptions in the model may exaggerate the potential for CDM; with shares of the economy participation in the CDM, rather than specific projects of different sizes, there are no economies of scale in the transaction costs, which implies that even the very smallest potentials will be made use of (if profitable).

[8] Whenever emissions are reported on a per year basis it refers to the annual average of the five years of the first commitment period under the Kyoto Protocol.

[9] There are several reasons relating to the model that explain why this estimate should be low. One is that with relatively modest emissions growth and no transactions cost in the IET market, permit prices are relatively low (i.e. the price differential is small). Another is that capital is region specific in the DEEP model, and the estimated carbon leakage would have been higher had capital been assumed to be globally mobile.

The *CDM* scenario suggests a theoretical potential (i.e. with 100% participation) where the CDM would be responsible for more than half of the emissions reductions under the Kyoto Protocol. This is a volume of CERs far greater than other studies have estimated. A participation rate of 10% gives a volume of CDM sales (102 Mt Ce/year) that is roughly consistent with the estimate by Michaelowa and Jotzo (2005) (99 Mt Ce/year).[10] Even this volume is high compared to the number of CDM projects currently in the pipeline - reported by CDM Watch (2005) to be 18-29 Mt Ce/year. The participation rate that is consistent with such a volume of CDM sales is below 2%.[11] New rules adopted by COP/MOP1 in Montreal (UNFCCC 2005b) that open the door for a broader range of CDM projects that are not strictly project based can, however, be expected to increase the participation rate.

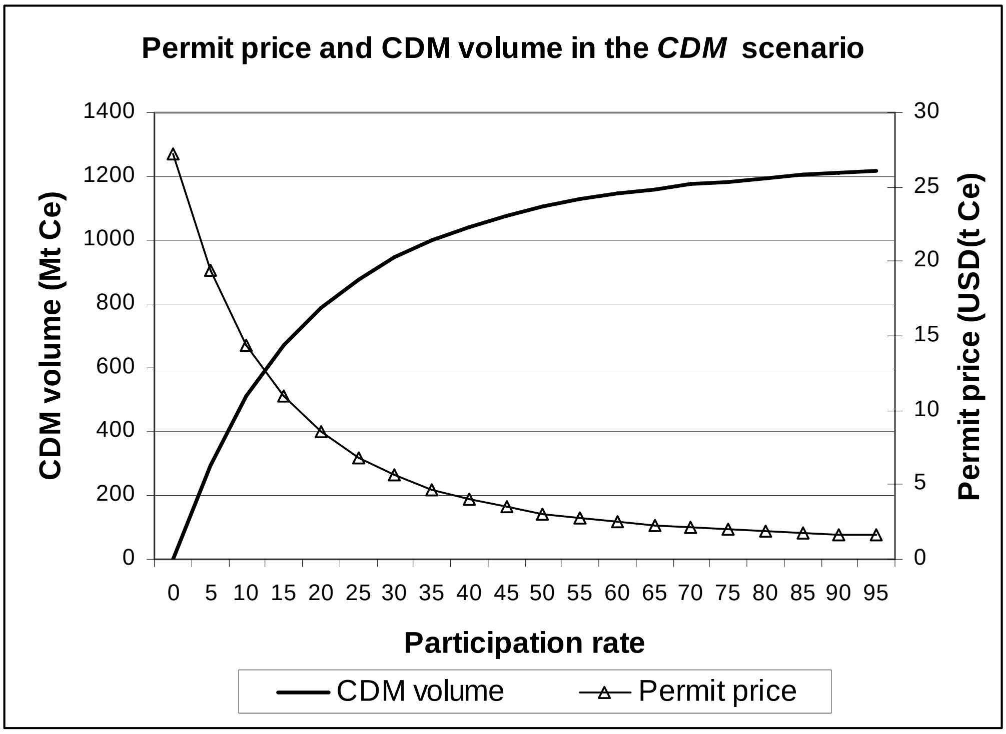

Figure 4.1: Permit price ($2001/t Ce) and CDM volume (Mt Ce) by participation rate)

The CDM might reduce carbon leakage as the price differential on emissions between Annex B and non-Annex B countries is reduced. The modelling results are consistent with this expectation. Furthermore, a higher participation rate, which will produce higher CDM sales, and the greater reduction in the international permit price associated with the increased volume of CDM sales, results in lower estimates of carbon leakage. The model results show a significant decrease in carbon leakage from 6.3% to less than 0.06% at high participation rates (see figure 4.2). However, the leakage is not uniformly decreasing with an increasing

[10] In their study Michaelowa and Jotzo scaled back the abatement cost curves to 10%. Thus, in one sense this might not have any significance beyond showing that even using a rather different model, we find the same volume of CDM sales if we make a similar assumption regarding the “participation rate”.

[11] CDM Watch (2005) provides a low estimate of 328 million CERs in pipeline, and a high estimate of 530 million CERs. These numbers were converted to Ce and divided by the 5 years of the first commitment period.

participation rate as the leakage does start to climb slowly at higher rates. The reasons for this are explained in the next section.

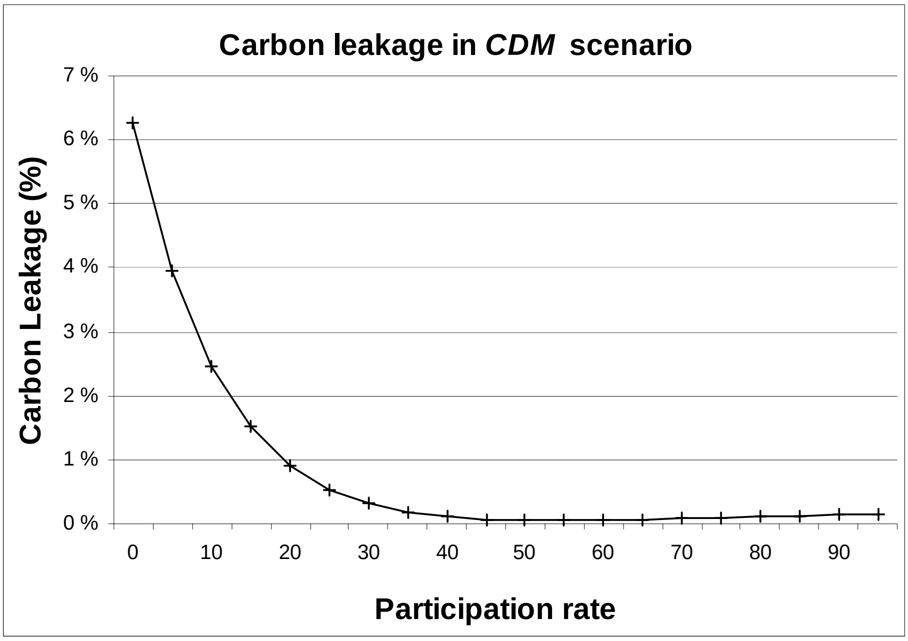

Figure 4.2: Carbon leakage in CDM scenario (per cent by participation rate)

Table 4.1 shows emissions (Mt Ce, annual average) for all three scenarios, using a 10% participation rate for the *CDM* scenario. The numbers show that at what might be a realistic participation rate (a realistic number of CERs generated), carbon leakage can be reduced by about three fifths from what it would have been without the CDM.

Region	***No-Kyoto***	***IET-only***	***CDM 10%***
Annex B	3653.7	3209.2	3209.2
China	2160.7	2166.9	2159.7
India	668.5	670.0	669.4
Brazil	164.8	165.4	165.4
Asia	1451.8	1457.8	1454.7
Africa and Latin America	1770.2	1777.8	1773.4
Non-participating regions	2426.2	2432.3	2430.4
Change from no-Kyoto	-	-416.6	-433.5
Total carbon leakage	-	27.9	10.9
Leakage (%)	**-**	**6.3 %**	**2.5 %**

Table 4.1: Annual emissions and carbon leakage (Mt Ce) under the three scenarios (with 10% participation rate for the CDM scenario).

4.1 Explaining the carbon leakage results

In section 2 the various factors that determine the magnitude of carbon leakage, and how leakage will differ between countries, were mentioned, but they were not explored in any detail. This section will break down the above results from the *CDM* scenario in two different ways that will help analyze the importance of some of these factors. First, the contribution to carbon leakage from each of the two mechanisms that are the principal drivers in the relationship between the CDM and carbon leakage will be analyzed separately. Second, variations in carbon leakage across countries (or regions) will be explored.

Two additional model runs were created in order to analyze separately the two mechanisms that determine how the CDM influences carbon leakage. These models runs are both imperfect approximations of the separate influence of each mechanism, but they are useful nonetheless. In the first model run the effect of the CDM on carbon leakage *through the permit price* is analyzed by allocating to Annex B countries additional permits equivalent to the CDM sales. In other words, the changes in carbon leakage resulting from changes in the permit price are isolated through a device that reduces the permit price without having any costs associated with the implementation of CDM projects.[12]

The second model run is used to analyze how the cost of CDM project implementation (resource reallocation) affects carbon leakage by forcing CDM host countries to reduce their emissions as much as they would under the CDM scenario (at the different participation rates), but without generating any credits than can be sold to Annex B countries. Emissions will in part be reduced because baselines become more restrictive at higher participation rates (as in this model run baselines must equal emissions *after* CDM credits have been sold in order to reproduce the cost of implementation), and these reductions must be subtracted from the overall change in emissions in CDM host countries.

The results of the two additional model runs can be seen in figure 4.3. The first thing to notice in the figure is that the relationship between the permit prices and carbon leakage is exactly what we should expect it to be: Carbon leakage decrease uniformly with a decreasing permit prices (or increasing allocation of permits to Annex B countries). This effect is strong, reducing carbon leakage to CDM host countries from 21.7 Mt Ce/year at 0% participation to 4.8 Mt Ce/year with 100% participation.

The effect on carbon leakage of the second mechanism is smaller and has two parts to it. The model results show that implementation of CDM projects produces a small decrease in carbon leakage at low rates of participation, and a slight increase for higher rates. The slight increase that shows up at higher rates is a product of the simple fact that the share of emissions for which leakage can potentially be reduced is declining linearly with an increasing participation rate. If this linear decrease were subtracted from the curve, we would see emissions decreasing in inverse proportion to the participation rate.

The interesting result is that in CDM host countries, the emitting activities that do not implement profitable CDM projects are still *reducing* their emissions. Implementing CDM projects does reduce fossil fuel prices (with mixed results only for gas). The magnitude of this effect is quite small as the markets for fossil fuels are highly internationally competitive, and the price is therefore relatively insensitive to small changes in local demand. It would still seem intuitive to expect this to increase demand for fossil fuels from the “non-participating” activities. For some sectors, such as agriculture, such an increase in fossil fuel demand – and in emissions can indeed be found. Also, the emissions *intensity* of most non-participating activities does increase as the price shift induces them to substitute towards greater use of fossil fuels. But there is also another effect that has an impact on the emissions from these

[12] One imperfection of this approach is the income effect as Annex B countries are endowed with more permits.

activities: The prices for non-fossil fuel goods are more sensitive than prices for fossil fuels to local changes in demand, and as implementing CDM projects implies substituting from fossil fuels to other inputs, the prices for these other goods tend to increase. Prices increase the most in the electricity sector (in all regions except Brazil, where prices decrease). This price increase for inputs is sufficient to increase unit production costs, and the consequent drop in demand results in an output reduction. For all regions except China the increases in the emissions intensity and the decreases in output more or less offset each other across sectors. It is the reduction in emissions from the electricity sector in China that is the main reason the net result is an emissions decrease (see further discussion below).

Figure 4.3 also shows the sum of the two mechanisms as a separate curve. The shape of this curve is the same as the carbon leakage found in the CDM scenario (i.e. with both mechanisms operating simultaneously), but the magnitude is somewhat different.

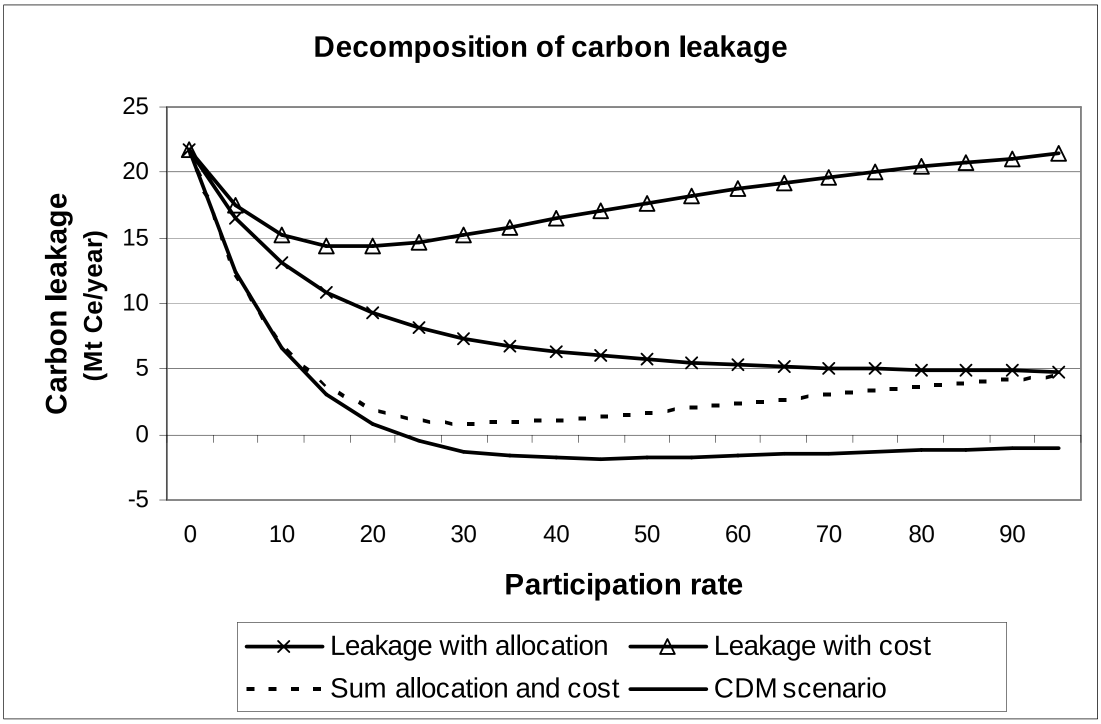

Figure 4.3: Decomposition of the contributions to carbon leakage.

Figure 4.4 shows carbon leakage by region (and by participation rate). The absolute leakage to each region (country) varies significantly (from 6.2 Gt Ce/year for China to 0.5 Gt Ce/year for Brazil), but here it has been normalized to unity for each region at 0% participation to allow easier comparison across regions.

India, Africa and Latin America, Asia and the non-participating countries, all have uniformly decreasing carbon leakage for increasing participation rates. These curves look a lot like the global curve shown in figure 4.2 (which is the weighted average of these individual curves). The two outliers, Brazil and China, who do not display the same uniform relationship, are the interesting cases.

Brazil (and South Korea) has often been identified as a special case in studies on the CDM, and on the trade and welfare effects of Kyoto Protocol implementation. Hourcade and Shukla (2001) explain why this is so: “Brazil and South Korea […unlike other non-Annex I regions…] are net importers of fossil fuels and have a high relative dependence on exports of iron and steel and non-ferrous metal products. In addition, in Brazil these products are far less intensive in fossil energy than in many other economies. Brazil gains from lower prices for fossil fuel imports and higher prices for exports of iron and steel and non-ferrous metal products." Translating this to our setting it means that Brazil will find few profitable CDM projects in the energy intensive industries as they are less intensive in fossil energy. Furthermore, being less dependent on fossil fuels, a change in the fossil fuel prices (induced though change in the IET market) will have a smaller impact (in relative terms) on Brazil than on other economies. These are two reasons why carbon leakage to Brazil might be expected to be less sensitive with respect to the CDM than it is in other countries. An initial and very small increase in leakage to the electricity sector and energy-intensive sectors in Brazil seems to be caused by lower fossil fuel prices. At participation rates above 20% the trend is reversed as the output level (and emission) decrease as other prices increase.

China has a relatively coal-dependent economy. In particular the electricity sector relies more heavily on coal in China than it does in the other CDM host countries (and the electricity sector in China also uses relatively little gas). Consequently, many profitable CDM projects can be found in the electricity sector in China. When these projects are implemented (and electricity sector output is reduced), the electricity price increases to the extent that overall demand for electricity is decreased. This effect is dominant in the overall results; when the net emissions change for CDM host countries is a reduction of 5.2 Mt Ce/year at 10% participation, emissions from the electricity sector in China contribute with a reduction of 3.4 Mt Ce/year. In total (i.e. across sectors) China accounts for about one third of the total net change in leakage for all CDM host countries (while making up only 19% of the total value of output in all these countries – in 2001 in the GTAP data base).

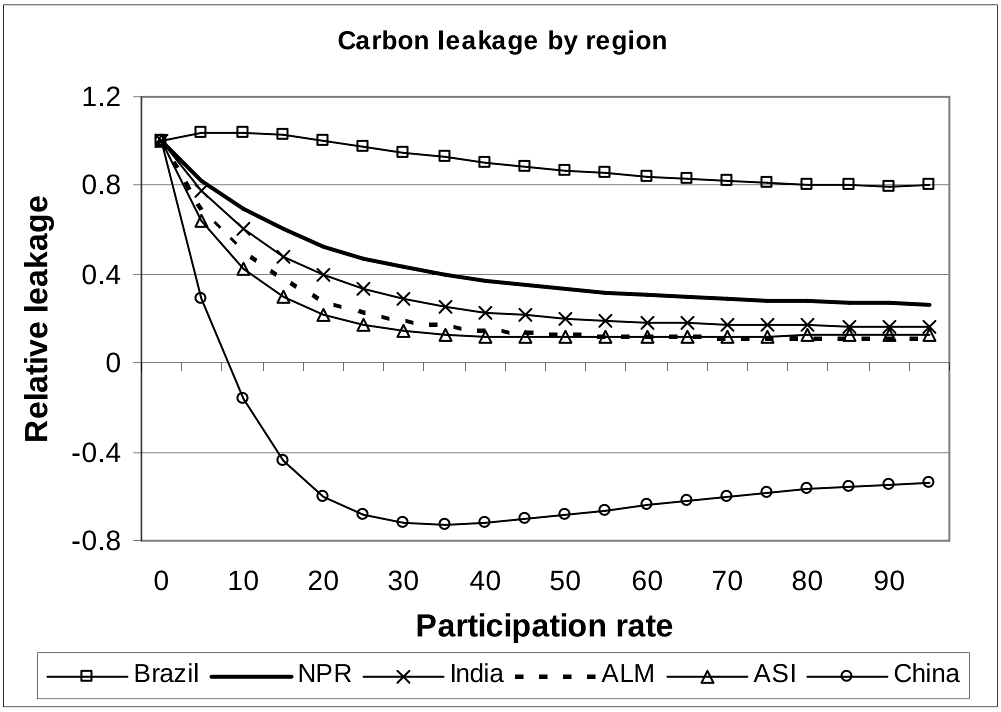

Figure 4.4: Carbon leakage by region.

4.1 Sensitivity analysis

The results from a CGE analysis can be very sensitive with respect to model structure, choice of values for model parameters, and scenario assumptions. A sensitivity analysis conducted on two such important assumptions indicates that the main results are robust.

Bernstein et al. (1999) argue that the choice of Armington elasticities has a particularly strong influence on estimates of carbon leakage. In particular they find that reducing the Armington elasticities will decrease estimates of leakage. In the DEEP model the standard assumptions are an elasticity of substitution of 4 between domestic and imported goods, and of 8 between imports from different regions. Figure 4.4 shows how the results differ for other assumptions on elasticity; for the *Armington high* and *Armington low* cases the assumed elasticities are, respectively, 2 and 8 for substitution between domestic and imported goods, and 4 and 16 for substitution between imports from different countries. In the *Armington high* case the carbon leakage is indeed higher, 11.9% with no CDM projects (versus 6.3% in the standard case). Similarly, in the *Armington low* case leakage is much lower – only 2.9%. For both the *Armington high* and the *Armington low* cases though, the relationship between the CDM and carbon leakage displays the same pattern across participation rates; with increasing participation carbon leakage decreases, rapidly at first, and then slower (even climbing a bit towards the end, for reasons explained earlier). Thus, the Armington assumptions are a key determinant of the estimated *magnitude* of carbon leakage, but they do not significantly affect how the CDM influences carbon leakage.

Another important assumption is how much hot air will be sold on the IET market. If we relax the assumption in the standard scenarios that no hot air will be sold, and allow Russia to sell 50% of its hot air, this results in a dramatic drop in permit prices (to $14.1 as compared to $27.2 at 0% participation). This means that the initial carbon leakage is much lower, as the price differential is smaller, and the leakage is reduced even further than in the standard scenario as permit prices become extremely low. However, the shape of the curve is the same as in the standard scenario, as can be seen in figure 4.4. It should be added that despite reduced carbon leakage, global emission are almost 1% higher when half the hot air is released onto the market.

The sensitivity analysis indicates that our main results are relatively robust with respect to how the CDM influences carbon leakage. The estimates of the initial magnitude of carbon leakage permit prices and CDM volumes may change, but the influence of the CDM on carbon leakage remains the same across assumptions; the CDM reduces carbon leakage.

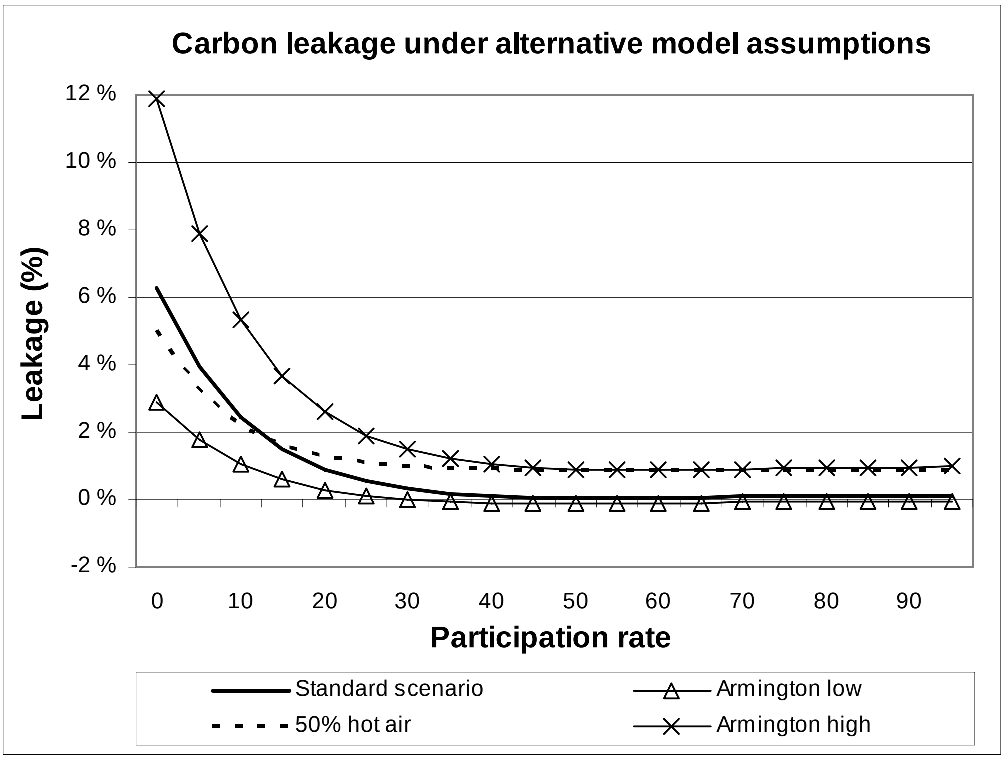

Figure 4.4: Carbon leakage under alternative model assumptions

5 Conclusions

The objective of this paper is to study how the CDM influences carbon leakage through market effects. The analysis revealed that the participation rate is a key determinant when analyzing this relationship. Other mechanisms through which the CDM might influence global emissions, such as project-specific leakage, or technology and knowledge spillovers, have not been analyzed.

The main finding of this paper is that the CDM has the potential to reduce the magnitude of carbon leakage under realistic assumptions. Primarily this is the result of the potential of the CDM to significantly reduce international emissions trading permit prices. Furthermore, the CDM is likely to reduce carbon leakage even at relative low levels of CDM activity (as compared to the theoretical potential). The CGE model results show that at a participation rate of 10%, which corresponds to roughly 100 Mt Ce/year in CDM sales, carbon leakage can be reduced by about three fifths.

One weakness of the model used in this study is that all sectors consist of only one “firm”, i.e. there is no heterogeneity in firm size of technology within a sector. If leakages within CDM host countries were to take the form of small increases in emissions in small activities, these would most likely not make for profitable CDM projects (as there are fixed costs). This is one reason why leakage within CDM countries might be underrepresented in the results – and this is an issue it could be interesting to analyze using a different model.

It is important to stress also that the conclusions rely heavily on the assumption that the baseline methodologies will be consistent with the UNFCCC rules. Kallbekken et al. (2006) discuss how reasonable this assumption is. The authors find that while the methodology that is argued to be most consistent with the rules might prove too demanding to implement, there may be ways to simplify the methodology, and leakage is also reduced if other methodologies are used.

The sensitivity analysis showed that the estimated magnitude of carbon leakage is sensitive with respect to some of the key assumptions underlying the model (in particular assumptions concerning Armington elasticities), but that the main result - that the CDM can significantly reduce carbon leakage - is relatively robust.

The main contribution of this paper is to stress how the CDM might reduce carbon leakage through market prices, especially through the permit prices in the international emissions trading system. Along with considerations of endogenous technological change this is one of the factors that need to be incorporated into any more comprehensive analysis of carbon leakage under the Kyoto Protocol. Furthermore, the paper shows that at relatively low rates of participation (below 10%) promoting greater use of the CDM would be an effective means to reduce carbon leakage – in particular promoting the CDM in countries (such as China) that have relatively emissions intensive economies.

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